CHONDRULE PRECURSOR AGGREGATES IN UOC'S: PETROGRAPHY AND HISTORY

P. Russell, Lunar and Planetary Institute, Houston, TX 77058, G. E. Lofgren, SN-4, NASA Johnson Space Center, Houston, TX 77058.

A model for the origin of chondrules based on dynamic crystallization experiments of chondrule melts proposed by Lofgren [1] predicts a complete spectrum of melting of precursor aggregates from barely perceptible to complete. Examination of several unequilibrated ordinary chondrites from the Antarctic collection revealed the presence of fragmental aggregates comprised of clastic olivine and pyroxene varying from very fine-grained to coarse. Many fragmental aggregates contain fragments of chondrules or even whole chondrules. These aggregates show varying degrees of partial melting. Nebular rims on some confirm a nebular origin. These aggregates are remnants of the chondrule forming process, precursors caught before transformation into chondrules.

Techniques: We examined polished thin sections of 22 ordinary chondrites from the Antarctic meteorite collection. All were type 3.0--3.4, save a few simply designated type 3. Over 100 particles that appear to be aggregates of previously formed chondrule material were identified and studied. Some of the most definitive of these particles are discussed in this abstract. Mineral analyses, back-scatter electron images, and chemical x-ray maps were collected with a Cameca SX-100 electron microprobe at JSC. Mineral standards were used for quantitative analyses.

Petrography: Several aggregates are described in an attempt to show the range of aggregate types. Many of these aggregates resemble the agglomerate olivine (AO) chondrules of [2] and the fine-grained aggregates described by [3]. In general, however, the aggregates described here are larger, coarser grained, and more commonly contain chondrule and larger mineral fragments. **Fragmental aggregate (BP) with nebular rim:** LEW 86018,38, P-2 is comprised of 4 BP fragments. The largest fragment is coarsely barred with large olivine dendrites. The 2nd at one end is a more finely barred chondrule. At the other end is a much finer, BP. The smallest fragment is also finely barred. The boundaries between the fragments are sharp and free of debris. The fine BP fragments have a mesostasis much more enriched in Na, Al and Ca than the coarser fragments. There are clastic pyroxenes of similar composition attached sporadically around the perimeter and the entire fragment is enclosed in a nebular rim of Huss matrix [4] mixed with sulfide. The BP fragments are similar in composition and probably formed in a single event, were then fragmented, aggregated, coated with clastic debris and then the nebular rim. **Fragmental aggregate:** LEW 86018,38 P-7 is more diverse and is comprised of several fragments: a BO fragment, a clastic aggregate with a large olivine crystal 0.5 mm long, and smaller olivine crystals and BP fragments. The BO fragment shows signs of partial melting prior to aggregation. The clastic aggregate consists of anhedral to subhedral olivine and pyroxene grains with some angular faces and appears to have a clastic texture. The large olivine is distinctly more Mg-rich. The boundaries of the large fragments are sharp and arcuate. There is no unequivocal nebular rim, but a partial rim is present. The fragments probably formed in different events and aggregated with other crystals and fragments sequentially. **Clastic olivine aggregate:** ALH 83010,26 P-17 is a rounded, fine-grained (<25 µm), olivine-rich clastic aggregate with minor sulfide and metal. The sulfide and metal are concentrated near the rim and are generally angular and interstitial. The dominant mineral is olivine which is more Fe-rich than the Ca enriched interstitial areas. It is difficult to be sure, but the larger crystals appear to be olivine and the smaller ones pyroxene based on the silica x-ray map. The olivine and pyroxene appear to have similar Fe/Mg ratios. There is slight partial melting and sintering. This clastic aggregate is part of a larger fragmental aggregate that contains coarse and fine barred and porphyritic chondrule fragments. **Fine-grained, clastic aggregate with Fe-metal and sulfide:** ALHA 76004,9 P-2 consists of a largely metal-free core of coarse, rounded olivines, $Fo_{3-11,}$ surrounded by an outer zone of finer, more angular olivines richly interspersed with concentrations of metal and sulfide. The circumference of the particle is marked by an uneven distribution of finer pyroxene grains. Similar pyroxenes are enveloped in an unmistakable nebular rim that encloses the whole particle. The close-packed texture of rounded grains in the center show evidence of partial melting. The large, often spherical, metal/sulfide concentrations in the outer zone indicate some heating has occurred, but the more angular shape of the olivine crystals suggest the degree of partial melting was less than that experienced by the inner zone. These different heating histories suggest the inner portion existed before the outer material was added. The fringe of fine pyroxene grains on the perimeter accumulated later. The pyroxenes enclosed in the rim appear to be similar. We think this aggregate retains the Fe-metal because it was not melted sufficiently for the metal to migrate out and form a typical chondrule melt. **Olivine aggregate with BO fragment:** ALHA 76004,25 P-2 is a clastic aggregate of olivine with one large, BO fragment. There is matrix or mesostasis marked by Al and Si enrichment, but lacking Na. There is no discernible pyroxene and little evidence of melting. The BO fragment and the enclosing olivine grains are similar in composition and probably formed nearby, and then aggregated into the present particle. **Coarse clastic aggregate:** ALH 83010,26 P-24 is an aggregate of Mg-rich olivine with a large grain size variation. Crystals are subangular to subrounded. The Si x-ray map indicates abundant pyroxene, but they are not as clearly defined and are generally finer grained than olivine. Fe-rich grains tend to be around the outer part of the particle. Na is irregularly distributed in the mesostasis and Ca enrichment is even more irregular and local and doesn’t correspond to the Na enrichment. There is rare sulfide in the particle and a sulfide rich rim with some Fe metal. It appears that the Mg-rich olivine aggregated first followed by more Fe rich olivine and pyroxene. An adjacent clastic aggregate, P-25, has more Fe-rich olivine and the Si x-ray map suggest pyroxene dominates. There appears to be more partial melting on one side with larger areas of mesostasis that show both Na and Ca enrichment. Many crystals have large relict cores with overgrowths. There could be a small, pyroxene rich chondrule included near the edge. These are simple clastic aggregates with local melting. **Chondrule with metal-rich clastic rim:** ALHA 76004,9 P-4 is a PP chondrule with large anhedral, twinned pyroxene grains with rounded boundaries and poikilitically enclosed olivine. A discontinuous rim of finer anhedral pyroxene and olivine, 5-20 micrometers, both rounded and angular, surrounds the chondrule. Large metal concentrations punctuate this clastic rim. The pyroxenes in the rim are generally more Fe-rich than those of the chondrule core. A few particles included in this rim consist of fine-grained silicate and sulfide-rich nebular rim material. One of these clumps of nebular rim material contains a small cluster of olivine and pyroxene grains similar to those dispersed in the clastic rim. The degree of partial melting that has taken place in the rim is uncertain as some rim grains are rounded, others angular. The compositions of the olivines and pyroxenes in the clastic rim are close to those in the nebular rim.

Discussion: All of the particles we studied are comprised, in whole or in part, of chondrules, fragments of chondrules, isolated crystals of olivine and pyroxene of various sizes, most likely from chondrules, kamacite and troilite, chondrite matrix, and fine-grained "nebular" rim material. Most significantly, these materials are aggregated randomly as clastic debris into these particles. Once these particles aggregate in the nebula, they are potential chondrule precursors. The boundaries of fragments in many particles suggest they were soft or partly molten when joined. In some cases the partial melting of the aggregate has been sufficient to join the melts of different fragments in a continuous melt. These heating events most likely would have occurred in the nebula because the meteorites in which they now reside are of such a low grade, <3.3, that such deformation could not have occurred after meteoritic aggregation. It is unlikely that shock or lithostatic compaction could account for the deformed joins or the melting because sufficient shock intensity would be evident. There is the possibility that the aggregates formed on a parent body prior to being incorporated into the present meteorite. But this would require a much more complicated sequence of events with multiple heating and aggregation events that contribute to formation of the aggregates that now reside in a UOC. The aggregation of a group of particles can also be identified as having occurred within the nebula by the presence of fine-grained nebular rim material [5] surrounding the entire assemblage. Typically this rim appears black in transmitted light, gray in reflected light, and a grainy light gray in back-scattered electron images. Unfortunately only a few aggregates have such rims.

Conclusions: The complex fragmental aggregates described here are distinct particles whose aggregation predates the formation in the meteorites in which they now reside and thus they must have been present in the nebula. All of these aggregates most likely form a spectrum of chondrule precursors with variable size, texture and composition. Their formation processes have strong implications for chondrule composition [6].

References: [1] Lofgren G. E. (1996) In *Chondrules and the Protoplanetary Disk*, R.H. Hewins, R.H. Jones, E.R.D. Scott, eds. pp. 187-196. [2] Weisberg M. K. and Prinz M. (1996). Ibid. pp. 119-128. [3] Hewins R.H. Zanda B. and Bourot-Denise M. (1996) *LPSC XXVII*, LPI, Houston, 537-538. [4] Huss, G.R. et al. (1981) *GCA*, **45,** 33-51. (5) Metzler K. et al. (1992) *GCA*, **56**, 2873-2897. [6] Lofgren G. E. (1997) this volume.